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Lean Six Sigma Application's in Improving the Quality of Briquettes Coconut Shell Charcoal Products

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Abstract A systematic and technical operational management methodology that aims to increase the performance of a manufacturing processes by eliminating waste is Lean Six Sigma. The aim of this paper is to analyze the problem of increasing demand for briquettes in the company BriqCo (Briquettes Coconut Shell Charcoal). In this paper, the company has a waste problem due to defective products to count to 10.2% of the total production of 169.298 kg. The high defects cause the company to sustain profit loss from the defect reproduction process and a drop in sales due to the unacceptable quality. This study uses the Lean Six Sigma: Define, Measure, Analyze, Improve, Control (DMAIC) methodology. The define phases use the SIPOC diagram to define the elements involved in the production process and value stream mapping. The measure phases to determine the sigma level based on the production results. The analyze phase uses a fishbone diagram to identify the root causes of problems. In Improve the application of the 5S method and Standard Operating Procedures (SOP) is proposed for a work improvement process aimed at improving the production process. In the control phase, the application of new SOPs is carried out to improve the production process and reduce errors. Based on the results, the initial sigma level reached 3.19. The causes of defects in briquette products are made up of human, material, mechanical, process engineering and environmental factors. With the application of 5S by SOP, the level of disability is expected to decrease by 50%.

Keywords: Lean six sigma, DMAIC, improve quality.

1. Introduction

It is only natural; every industrial company struggle to have a dominant market share. The struggle for dominance is represented in almost all market segments. For this purpose, the company targets increased revenue, which then depends on product quality. If the company want to increase sales, the cost and the quality of the products are one of the key attributes (C.R & Thakkar, 2019). Considering Six Sigma's success at Motorola, the Define, Measure, Analyze, Improve, Control (DMAIC) the method has gained popularity with industries that concentrate on improving quality. DMAIC is a systematic methodology which is an acronym for defining, measuring, analyzing, improving, controlling, and following whenever a defect or the root cause of an issue is very problematic to identify with routine checks. The main target of the Six Sigma methodology is reducing the number of Defects per Million Opportunities (DPMO). The number of DPMOs per increase in sigma level is given in Table I (Montgomery 2009). Six Sigma is implemented in both manufacturing and service industries (Muraleedharan et al 2017)

Table 1 DPMO per Sigma level increase.

Sigma level	Percentage of specification limit (%)	DPMO
1	30.23	697,700
2	69.13	608,700
3	93.32	66,810
4	99.379	6,210
5	99.9767	233
6	99.99966	3.4

DMAIC is used in this paper to minimize waste generated during product manufacturing of the BriqCo (Briquettes Coconutshell Charcoal). The define phase of the DMAIC methodology includes the initial observation of the process under investigation. The problems faced in this company appear in this phase, the problem is related to the waste that occurs in each process as well as the problem of defective products which result in company losses. The procedure is examined and a possible error reduction opportunity is identified. The tools used in this phase are the Current State Value Stream Mapping (VSM) diagram and the Supplier Input Processing Output Customer (SIPOC) diagram. In the measure phase, the data on the quality appearances and suitable variables are gathered. The analysis of the measurement method and current performance is finished by calculating the level of sigma. In the analysis phase, the analysis of the data collected in the measured phase is completed. Using tools such as brainstorming and cause and effect diagrams, various causes of the deviations involved in defect generation are identified. In the improvement phase, brainstorming related to suitable improvement is done. The improvements made during this phase are implemented, and the process's status is evaluated using the future state of VSM. In the control phase, efforts to maintain the improvements that have been made by creating new standards that are legalized in the SOP (Standard Operating Procedure) document

2. Literature Review

In the last several years, many companies have applied DMAIC to improve quality and reduce processing waste, such as C.R and Thakkar (2019) apply the Six Sigma DMAIC methodology in order to reduce the rejection experienced in the manufacturing of the doors fitting to a telecommunication cabinet. Ahmed (2019) implement DMAIC approach of Lean Six Sigma (LSS) to improve quality performance in a healthcare organization. Arafeh (2015) apply Six Sigma DMAIC methodology to consistently implement lean manufacturing principles and techniques in order to improve production at a company close by that produces metal doors, windows, and frames deemed fire resistant and safe. Alkahtani et al (2016) analyses the problem of increasing demand of flour in wafer biscuit production in Y Company using DMAIC methodology. This problem leads to decrease profit and external customer satisfaction. Kaushik and Khanduja (2009) successfully applied the Six Sigma methodology to the process industry to reduce water consumption of thermal power plants which can reduce costs. Prashar (2020) adopting Six Sigma DMAIC for environmental considerations in process industry environment. Sharma et al (2018) apply DMAIC Six Sigma approach to quality improvement in the anodizing stage of the amplifier production process. Guo et al (2019) apply integration of value stream mapping with DMAIC for concurrent Lean-Kaizen on an air-conditioner assembly line. Gandhi et al (2019) Apply six sigma DMAIC to reduce rejection of cylinder blocks in a casting unit. Jamil et al (2020) proposed DMAIC-based approach to sustainable value stream mapping towards a sustainable manufacturing system. Mishra and Sharma (2014) introduce a hybrid framework (suppliers, inputs, process, output and customers + define, measure, analyze, improve and control (SIPOC + DMAIC)) aimed at improving supply chain management (SCM) process dimensions in a supply chain (SC) network. Based on the literature that has been reviewed, this study uses the Lean Six Sigma (DMAIC) method to reduce briquette rejections and using VSM and SIPOC tools to examine the issue of rising briquette demand in the company BriqCo (Briquettes Coconutshell Charcoal).

3. Methodology

In this study aim to increase demand by reduce the wastes by implements LSS-DMAIC in the manufacturing of the BriqCo (Briquettes Coconutshell Charcoal). The The analysis done on the shop floor of the briquettes process established the foundation for the data provided in this study. Before the project is carried out, A detailed literature research is carried out on the study of the DMAIC model's phases and the various tools that can be used at every phase of the Six Sigma approach for SMEs. DMAIC is a five-stage sequential model where each stage has an established goal, requires inputs, and produces an output using the appropriate tools in accordance with the Plan-Do-Check-Act (PDCA) framework. The tools to be used in each step of the study are chosen based on the review of the literature and a brainstorming gathering with the owner and an expert academic. SIPOC analysis, Pareto analysis, control charts, value stream mapping (VSM), and fishbone diagrams, among others, are used in this study's different phases of the DMAIC model as show in Figure 1 below.

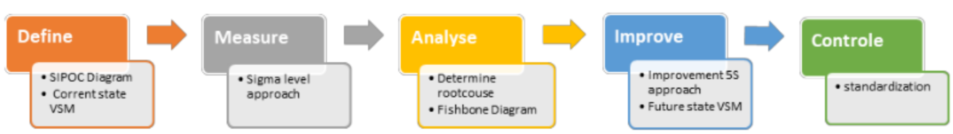


Figure 1 Flow Chart Methodology

4. Case Study

This study was conducted in an industry briquette which is coconut shell charcoal which is the raw material. This briquette product from BriqCo is specifically for export to countries in Europe, Africa, the Middle East and others. BriqCo in its production process adheres to the make to order system, where this company must meet buyer / consumer demands with a target of 26 tons each month. The major challenge faced by the industry is the high level of defect products with an average monthly defect of 10.2%. This section presents the implementation of DMAIC Six Sigma quality improvement programmed to the reinforcement production anodization process. Each phase of the DMAIC model is discussed with data analysis, results and discussion.

4.1 Define

Define phase of DMAIC model focusses on the observation of the process. The SIPOC analysis is conducted in this phase and document a process including its supplier as well as customer(s) (Yeung 2009). Figure 2 shows the SIPOC diagram for the briquette making process from start to finish.

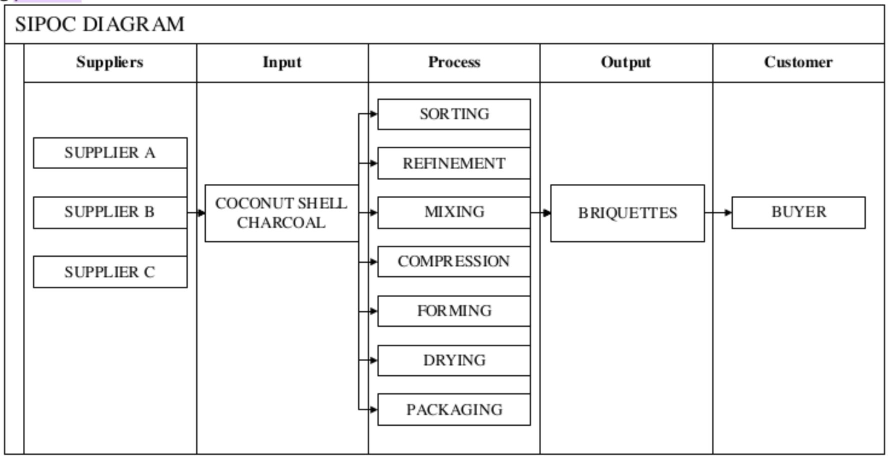


Figure 2 SIPOC diagram of briquette process.

Then current value stream mapping is conducted as show in Figure 3

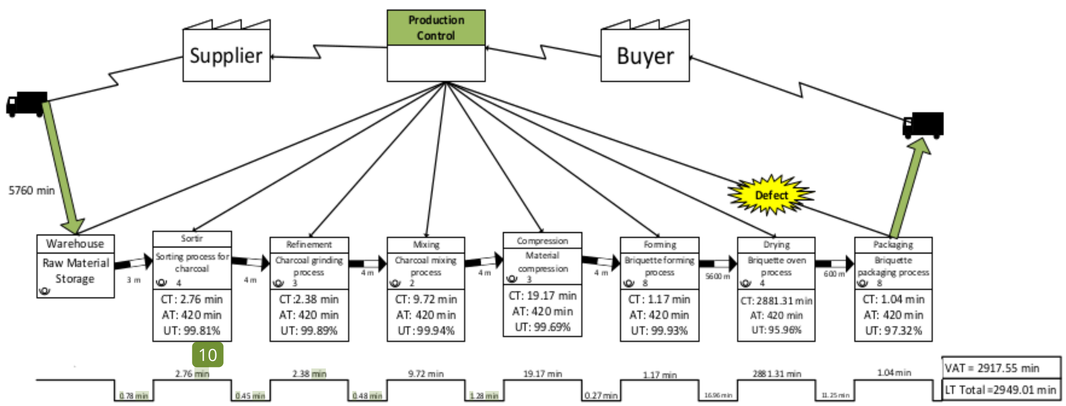


Figure 3 Current Value Stream Mapping.

Waste of defects occurs because the quality of the products does not meet the company's quality standards. The BriqCo company routinely distributes 20-26 tons of briquette products to the export market every month. Based on the production data for April-September 2020 which was obtained from the company, it was found that there were losses in the production process, namely the existence of defect products that did not meet the quality standards of 16.997 kg from the total production of 169.298 kg so that the percentage of defects was 10.02%.

4.2 Measure

The calculation of the sigma level of defect that occurs in the briquette production process at the BriqCo company as show in table 2 and 3 below.

Table 2 Calculation of Sigma Level of Defect (1).

Steps	Actions	Results
1	What process do you want to know	Briquette production
2	The number of products produced	30244
3	Number of failed products	2050
4	Calculate the failure rate	0.06778
5	The number of CTQ causes of failure	2

6	Chances of failure rate per CTQ characteristic	0.03389
7	Calculate the probability of failure per one million opportunities (DPMO)	33891.02
8	Convert DPMO into sigma value	3.33

Based on the results of sigma calculations that have been carried out using production data for the months of April-September 2020, it is found that the average BriqCo company is at the sigma level of 3.17 with a DPMO of 51,188.84. The calculation of the sigma defect level can be seen in table 3.

Table 3 Calculation of Sigma Level of Defect (2).

Month	Output (Kg)	Reject		Total (Kg)	% Defect	CTQ	DPU	DPMO	Level Sigma
		Form	Color						
Apr-20	30244	1332	718	2050	6.8%	2	0.0678	33891.02	3.33
Mei-20	19009	756	554	1310	6.9%	2	0.0689	34457.36	3.32
Jun-20	34287	1423	794	2217	6.5%	2	0.065	32330.04	3.35
Jul-20	29430	2298	1128	3426	11.6%	2	0.116	58205.91	3.07
Agu-20	31217	1576	1229	2805	9.0%	2	0.0899	44927.44	3.20
Sep-20	25111	3874	1315	5189	20.7%	2	0.2067	103321.3	2.76
Total	169298	11259	5738	16997	61.4%	2	0.6143	307133	19.02
Average	28216.3	1876.5	956.33	2832.8	10.2%	2	0.1024	51188.84	3.17

4.3 Analyze

The Analyst stage uses the fishbone diagram which is useful for knowing the root causes of waste that occur

a) Fishbone of Form Reject

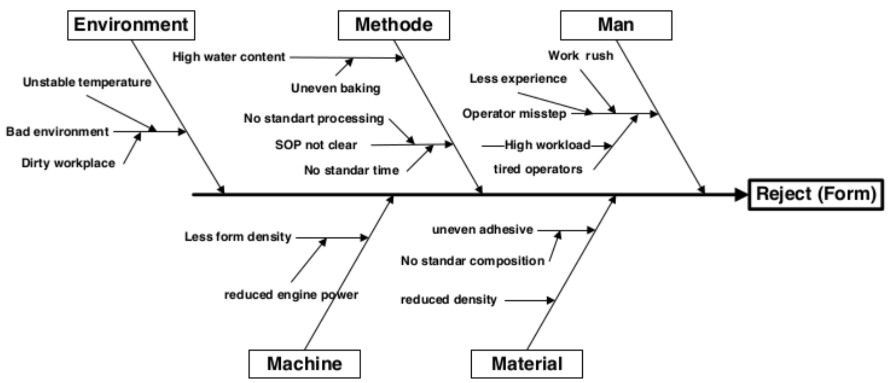


Figure 4 Fishbone diagram of form reject

Based on the analysis of the causes of deformities, there are several elements that cause disability as show in figure 4, among others;

• Humans, namely operator errors caused by being hasty, inexperienced, and tired due to heavy workloads.
• Material, namely due to uneven material caused by an unbalanced mixture, there is raw material, contamination and lack of density
• Machine, namely because of the less density of the printing machine which is caused by the printing press's lack of power and the machine's performance is not optimal with a small number of machines and high productivity causes minimal maintenance
• Environment is an unsupportive work environment caused by unstable room temperature and an unsanitary environment
• Method, namely high water content caused by uneven oven process and unstable process operating standards so that there is no standard process work and process standard time.

b) Fishbone of Color Reject

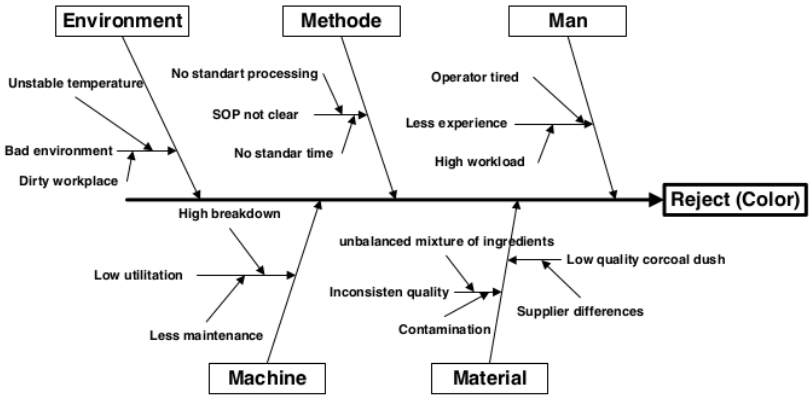


Figure 5 Fishbone diagram of color reject

Based on the analysis of the causes of color defect types, there are several elements that cause disability, among others;

• Humans, namely operator error caused by being hasty, inexperienced, and tired due to heavy workloads.

• Material, namely due to uneven material caused by an unbalanced mixture, there are raw materials, contamination and low quality of charcoal because it comes from different suppliers

• Machine, because machine performance is not optimal with a small number of machines and high productivity causes minimal machine maintenance

• Environment is an unsupportive work environment caused by unstable room temperature and an unsanitary environment

• Method, namely the standard operating processors that are not fixed so that there is no standard work process and standard process time.

4.4 Improve

At the improve stage, a corrective action plan was made based on the root causes of the known problems in the Analyze stage using a fishbone diagram.

a. 5S

1) Seiri: Identifying items in the form of tools or materials that are not needed. The stage of applying seiri at the sorting workstation is by separating the coconut shell charcoal professionally so that the coconut shell charcoal that has passed the sorting is really charcoal suitable for use.
2) Seiton: Storage of goods or tools in a structured and neat manner, so that when it is easier to find them when needed. The implementation stage of seiton is by storing charcoal raw materials based on the time of arrival, giving a sign in the form of a label for different charcoal raw materials suppliers.
3) Seiso: Keeping the work area environment and production equipment clean. The seiso application stage is by cleaning the equipment used after the production process so that the equipment remains clean and does not leave any residual material in the production process on the machine tools used.
4) Seiketsu (Standardize): Ensuring the stages of seiri, seiton, and seiso are going well. The stages of implementing seiketsu so that the 3s are carried out properly is by making SOPs (Standard Operating Procedures) and making regulations in the production process.
5) Shitsuke (Sustain): Familiarize the 5S culture in the work environment so that the work environment becomes comfortable. The stages of implementing sustain is by socializing and educating employees / operators to implement the 5S culture, after all employees know 5S and start implementing this culture, a monitoring process is needed so that the 5S culture is properly implemented.

b. Proposed standard operating procedures for the production process to prevent defects from occurring as show in table 4

Table 4 Proposed SOP for the production process.

Work Station	Proposed Improvement
Sorting	1. Doing the sorting of raw materials well
	2. Provide a sign / label of the sort based on the supplier
Refinement	1. Make sure the crusher machine is in good condition before use
	2. Clean the remaining crushed charcoal

	3. Perform regular maintenance to ensure that the machine is in prime condition and is always ready for use
Mixing	1. Make sure the mixer machine is in good condition before use 2. Using a machine that does not exceed the maximum capacity so that the machine can work properly 3. Ensure that the dosage of the composition is appropriate between the raw material for coconut shell charcoal and other mixed ingredients 4. Make sure the ingredients are evenly mixed before ending the mixing process by turning off the mixer machine 5. Ensure that the floor where the mixing results are poured is clean so that it is not mixed with dirt or dust which can affect the quality of the product produced. 6. Cleaning the mixer machine room after the mixing process so that the next mixing process is not contaminated with the rest of the previous mixing process. 7. Perform regular maintenance by ensuring the condition of the machine is in good condition after use.
Compression	1. Ensure that the ulen machine is in good condition before use 2. Perform cleaning of the ulen engine room after the compaction process so that the next compaction process is not contaminated with the remaining compaction of the previous process. 3. Perform regular maintenance by ensuring the condition of the ulen machine is in good condition, namely that the output hole remains tight so that the materials resulting from the compaction process are properly adhered
Printing	1. Make sure the printer is in good condition before using it so that the printout is really solid 2. Using a machine that does not exceed the maximum capacity so that the machine can work properly 3. Perform cleaning of the printing machine room after the printing process so that the next printing process is not contaminated with the remaining printing from the previous process 4. Make sure the cutting blades are sharp and suitable for size. 5. Perform regular maintenance by ensuring the condition of both the printing press and the cutting machine is in good condition 6. The process of placing the printout into a bin that does not exceed the capacity so that the printed briquette does not experience cracks due to the overlap of other briquettes on top and the air circulation runs well.
Drying	1. Ensure the condition of the oven room is in good condition 2. Using firewood that is completely dry 3. Ensure that the oven room temperature is stable +/- 100 degrees Celsius by using a thermometer
Packaging	1. Carry out the proper / inappropriate briquette sorting process carefully 2. Carry out the process, namely packaging the briquettes according to company standards into available packaging boxes weighing 1kg / 72pcs.

c. Future Value Stream Mapping

The implementation of the improve stage in the form of a proposed improvement in the production process using the 5S method is expected to reduce the defect rate from 10.2% to 5%. The function of designing the Future Value Stream Mapping is as a comparison between the current state of the company based on the proposed improvements which are expected to reduce the defect rate of the product with a certain target. The target of reducing the product defect rate by 50% means that the time lost due to defective products has changed, from 0.702 hours to 0.351 hours with the following calculations:

Lost Time Before Improvement

Calculation of time lost due to defective products is based on production data for the period April to September 2020. The following is a table of changes in total products.

Table 5 Lost Time Before Improvement.

Total Products / Time	**Per 6 months**	**monthly**	**daily**	**Per hours**
Total Defects	16,997 kg	2,832.83 kg	118.03 kg	16.86 kg
Total Products	169,29 kg	28,216.33 kg	1,1175.68 kg	167.95 kg
Lost time			**0.702 hours**	

Lost Time After Improvement

Calculation of lost time using a target of reducing the defect rate of the product by 50%

Table 6 Lost Time After Improvement.

Total Products / Time	**Per 6 months**	**monthly**	**daily**	**Per hours**
Total Defects	8,598.5 kg	1,416.42 kg	59.01 kg	8.43 kg

Total Products	169,298 kg	28,216.33 kg	1,1175.68 kg	167.95 kg
Lost time			**0.351 hours**	

Future value stream mapping as show in figure 6 below

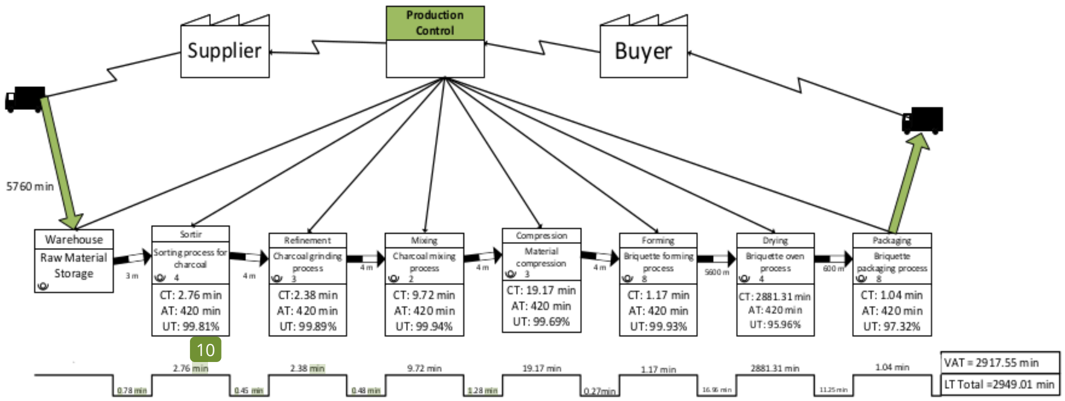
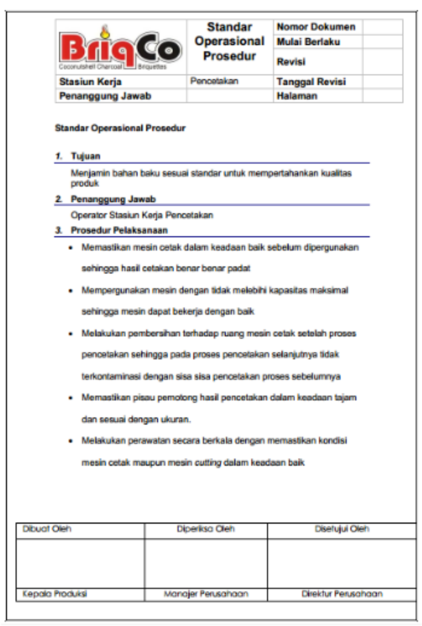


Figure 6 Future Value Stream Mapping

4.5 Control

The control phase is a stage in the form of surveillance efforts in maintaining all improvements that have been made. At this stage, the proposed improvement is to be made in the form of making SOPs (Standard Operating Procedures) at a certain time so that the resulting impact will have a good effect on the production process. Several SOPs were made, namely the Sorting Workstation SOP as show in figure 7



BriqCo

Standar Operasional Prosedur	Nomor Dokumen	
	Mulai Berlaku	
	Revisi	
Stasiun Kerja: Pencetakan	Tanggal Revisi	
Penanggung Jawab	Halaman	

Standar Operasional Prosedur

1. **Tujuan**
   Menjamin bahan baku sesuai standar untuk mempertahankan kualitas produk
2. **Penanggung Jawab**
   Operator Stasiun Kerja Pencetakan
3. **Prosedur Pelaksanaan**
   - Memastikan mesin cetak dalam keadaan baik sebelum dipergunakan sehingga hasil cetakan benar benar padat
   - Mempergunakan mesin dengan tidak melebihi kapasitas maksimal sehingga mesin dapat bekerja dengan baik
   - Melakukan pembersihan terhadap ruang mesin cetak setelah proses pencetakan sehingga pada proses pencetakan selanjutnya tidak terkontaminasi dengan sisa sisa pencetakan proses sebelumnya
   - Memastikan pisau pemotong hasil pencetakan dalam keadaan tajam dan sesuai dengan ukuran.
   - Melakukan perawatan secara berkala dengan memastikan kondisi mesin cetak maupun mesin cutting dalam keadaan baik

Dibuat Oleh	Diperiksa Oleh	Disetujui Oleh
Kepala Produksi	Manajer Perusahaan	Direktur Perusahaan

Figure 7 Sorting Workstation SOP

5. Conclusions

This study presents the utilization of DMAIC Six Sigma methodology, aiming to increasing demand by reducing wastes of briquettes in BriqCo (Briquettes Coconutshell Charcoal) company. First, SIPOC and current state VSM were used to understand the problem and identify the areas of improvement. Then were gathered for 6 months and analyzed in term of level of sigma to meet the target specification. Next, root causes were identified by using cause-and-effect analysis (fishbone diagram). Moreover, a brainstorming session was conducted with the owner and expert, which resulted in successful formulation of the solutions. Finally, the results of the research show Finally, the study's findings indicate that the initial sigma level was 3.19. Defects in briquette products are caused by a combination of environmental, human, machine, material, and method factors. It is anticipated that by implementing 5S through Standard Operating Procedures, the level of disability will decrease by 50%. The future research direction involves integrating DMAIC methodology with other quality tools, conduct the methodology in solving problems of other products.

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Conflict of Interest

The authors declare no conflicts of interest.

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